

Systems Neuroscience

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Talk Outline

- What is “systems neuroscience”?
- Some examples of systems
- Techniques
- Correlation vs causation

What is Systems Neuroscience?

Systems Neuroscience

Wikipedia Definition: Systems neuroscience is a subdiscipline of neuroscience and systems biology that studies the function of neural circuits and systems. It is an umbrella term, encompassing a number of areas of study concerned with how nerve cells behave when connected together to form neural networks. At this level of analysis, neuroscientists study how different neural circuits analyze sensory information, form perceptions of the external world, make decisions, and execute movements.

Systems Neuroscience

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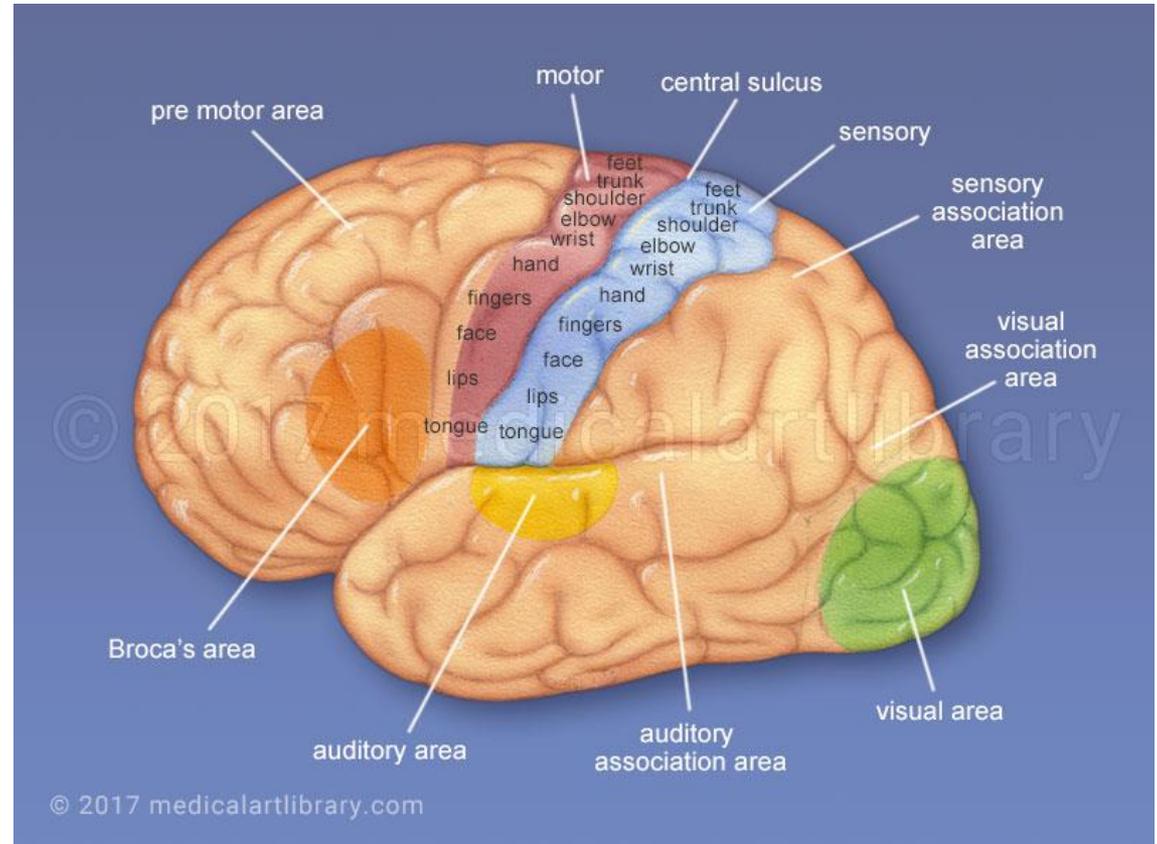
Researchers in systems neuroscience are concerned with the relation between molecular and cellular approaches to understanding brain structure and function, as well as with the study of high-level mental functions such as language, memory, and self-awareness (which are the purview of behavioral and cognitive neuroscience). Systems neuroscientists typically employ techniques for understanding networks of neurons while they function in vivo (e.g. electrophysiology (single or multi-electrode recording), in vivo imaging, fMRI, PET). ***The term is commonly used in an educational framework: a common sequence of graduate school neuroscience courses consists of cellular/molecular neuroscience for the first semester, then systems neuroscience for the second semester.***

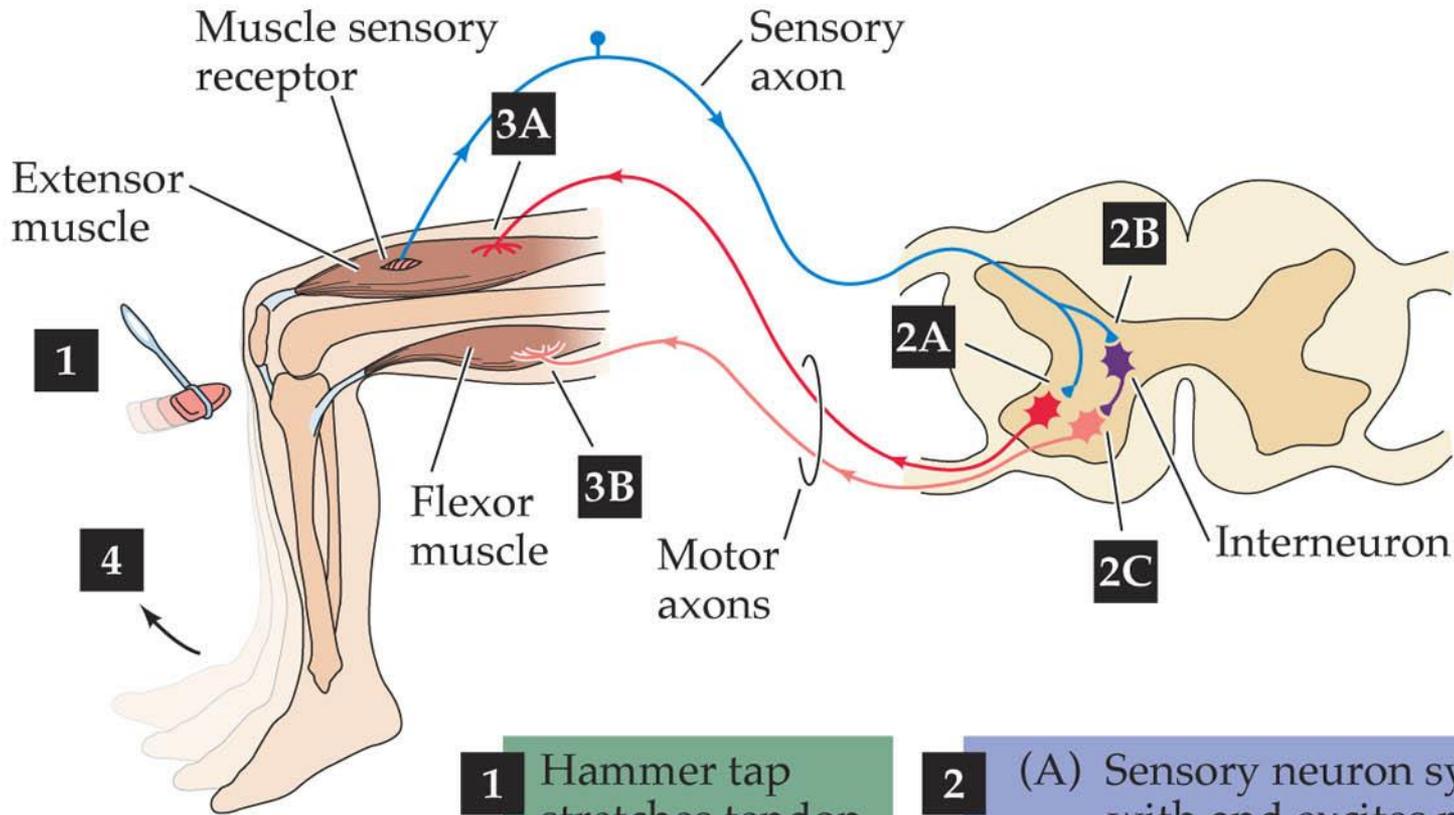
Systems

Circa 1982 (Doug as first year MSc in neuroscience program at McGill)

Visual system
Auditory system
Somatosensory system
Motor systems
Broca's area
Limbic system
Cranial nerves and reflexes

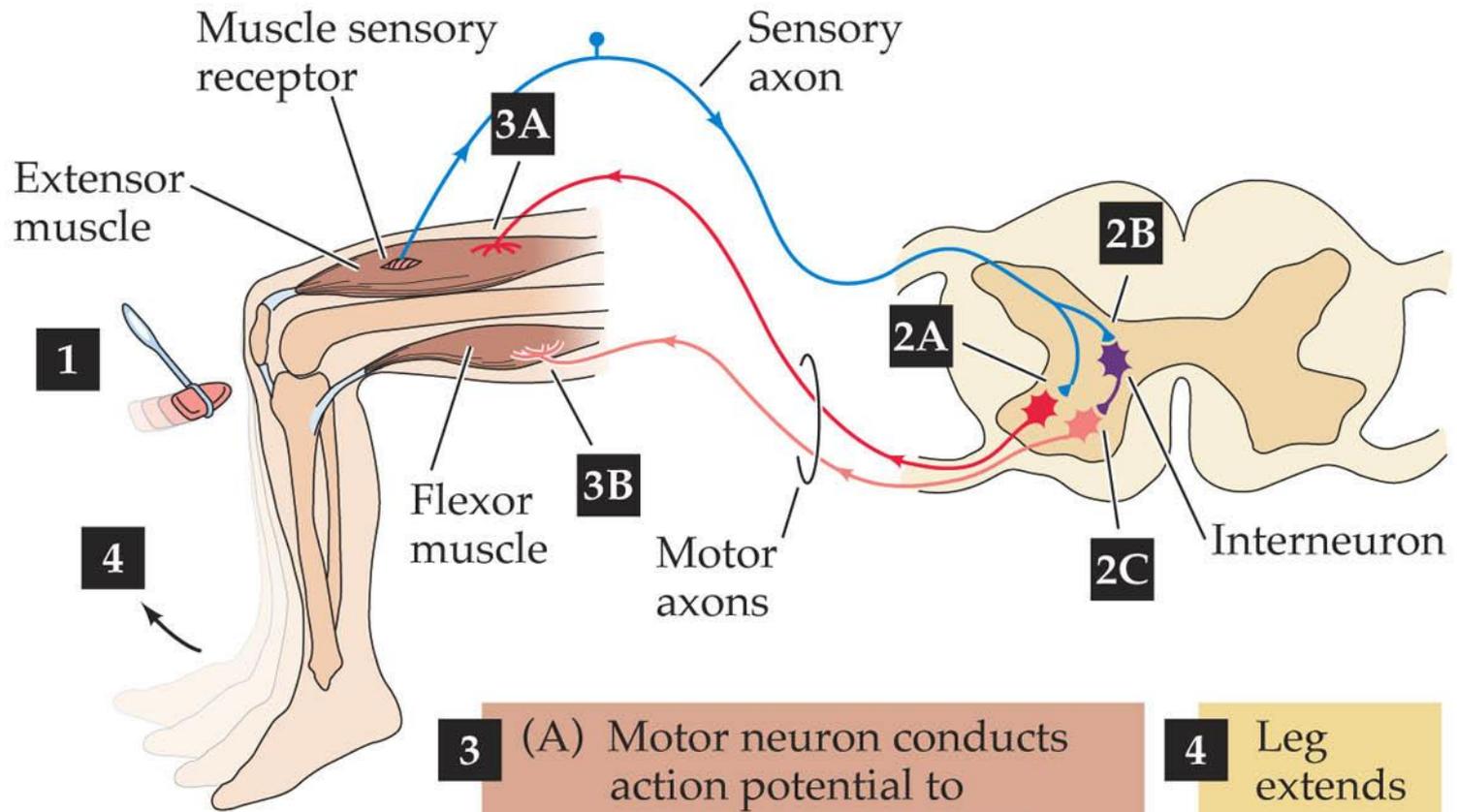
Association cortex





1 Hammer tap stretches tendon, which, in turn, stretches sensory receptors in leg extensor muscle

2 (A) Sensory neuron synapses with and excites motor neuron in the spinal cord
 (B) Sensory neuron also excites spinal interneuron
 (C) Interneuron synapse inhibits motor neuron to flexor muscles

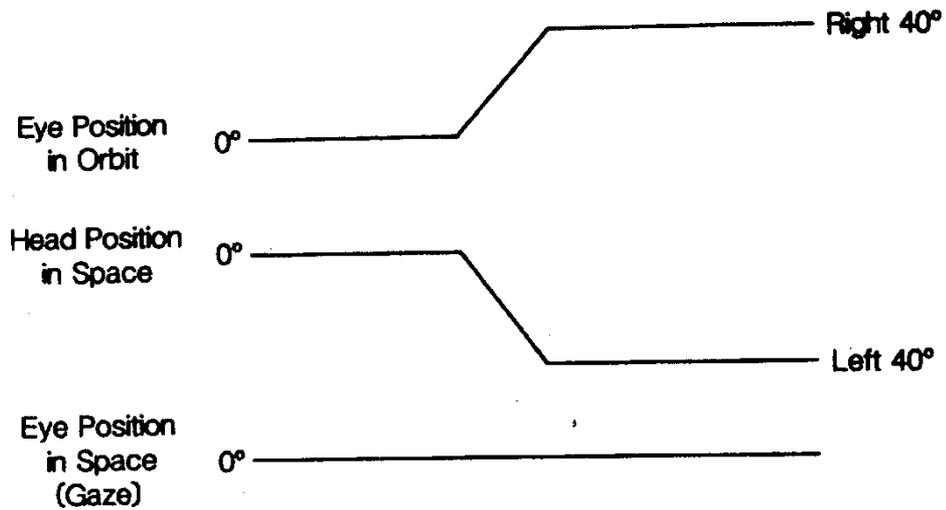
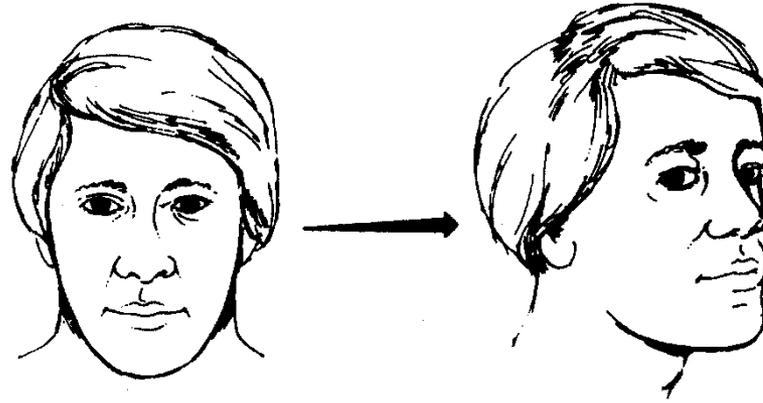


3 (A) Motor neuron conducts action potential to synapses on extensor muscle fibers, causing contraction

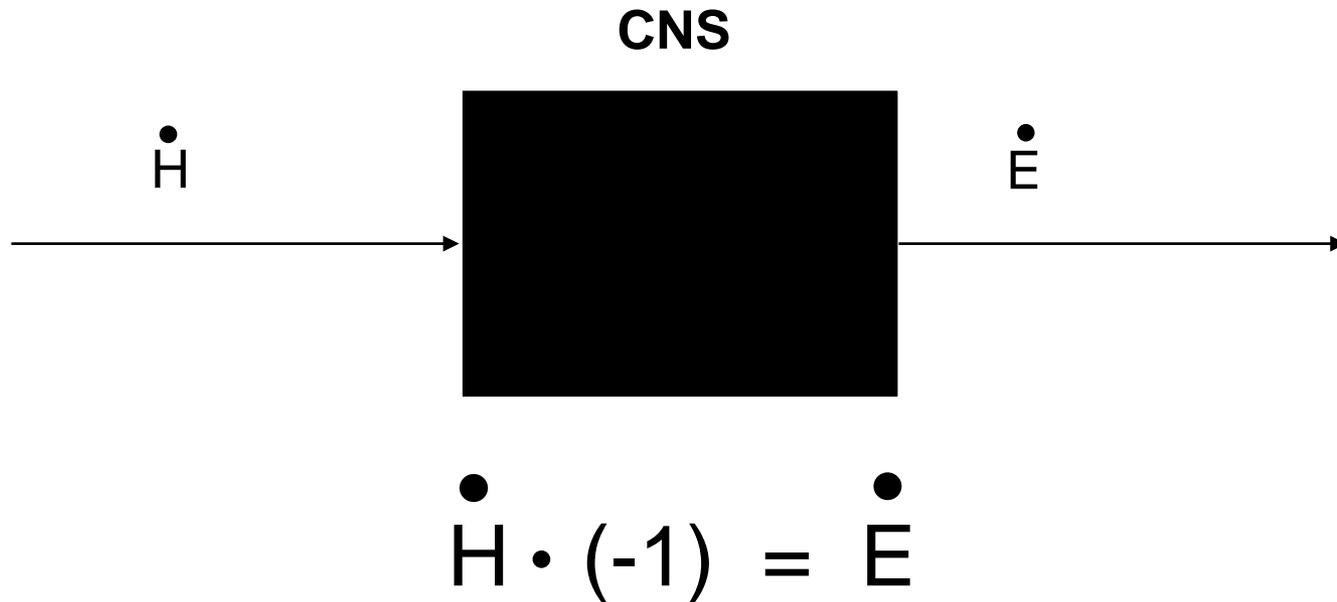
(B) Flexor muscle relaxes because the activity of its motor neurons has been inhibited

4 Leg extends

Vestibulo-ocular Reflex

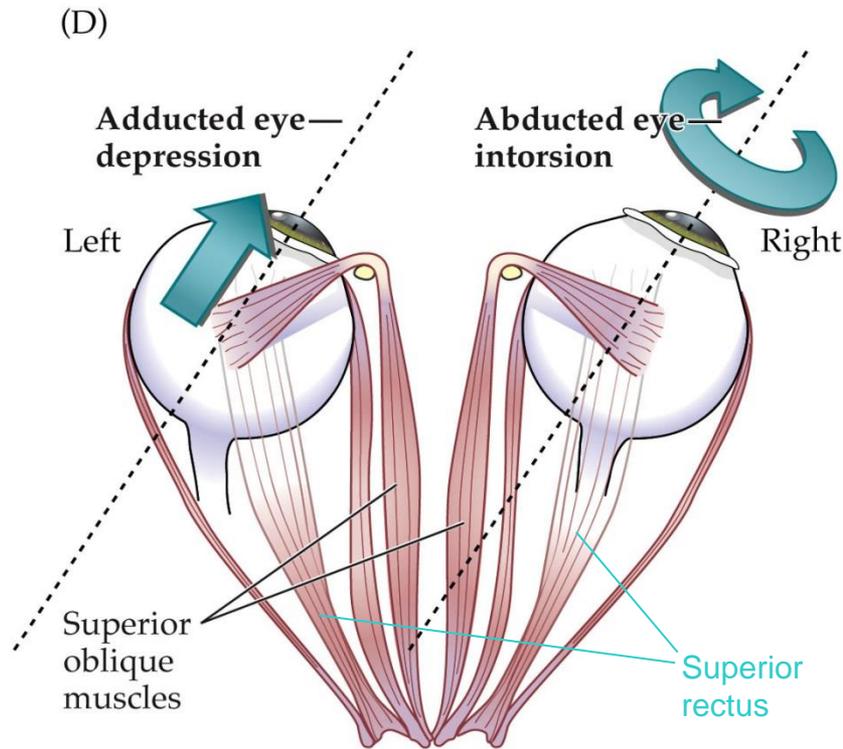


Vestibulo-Ocular Reflex

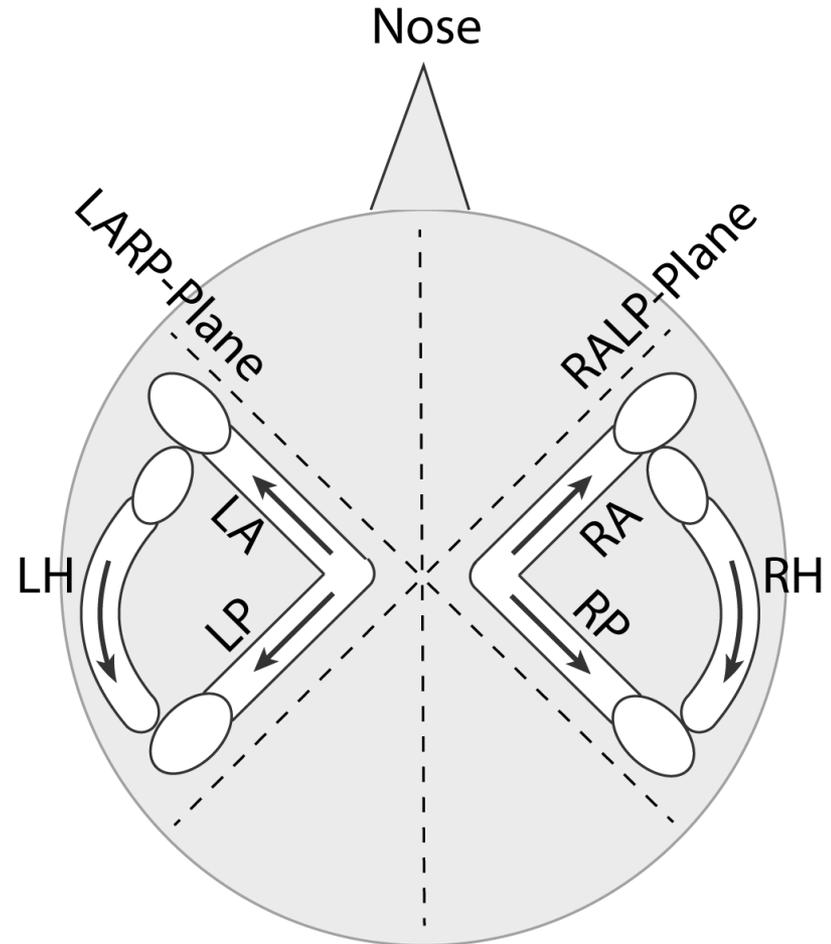


3-D organization of VOR

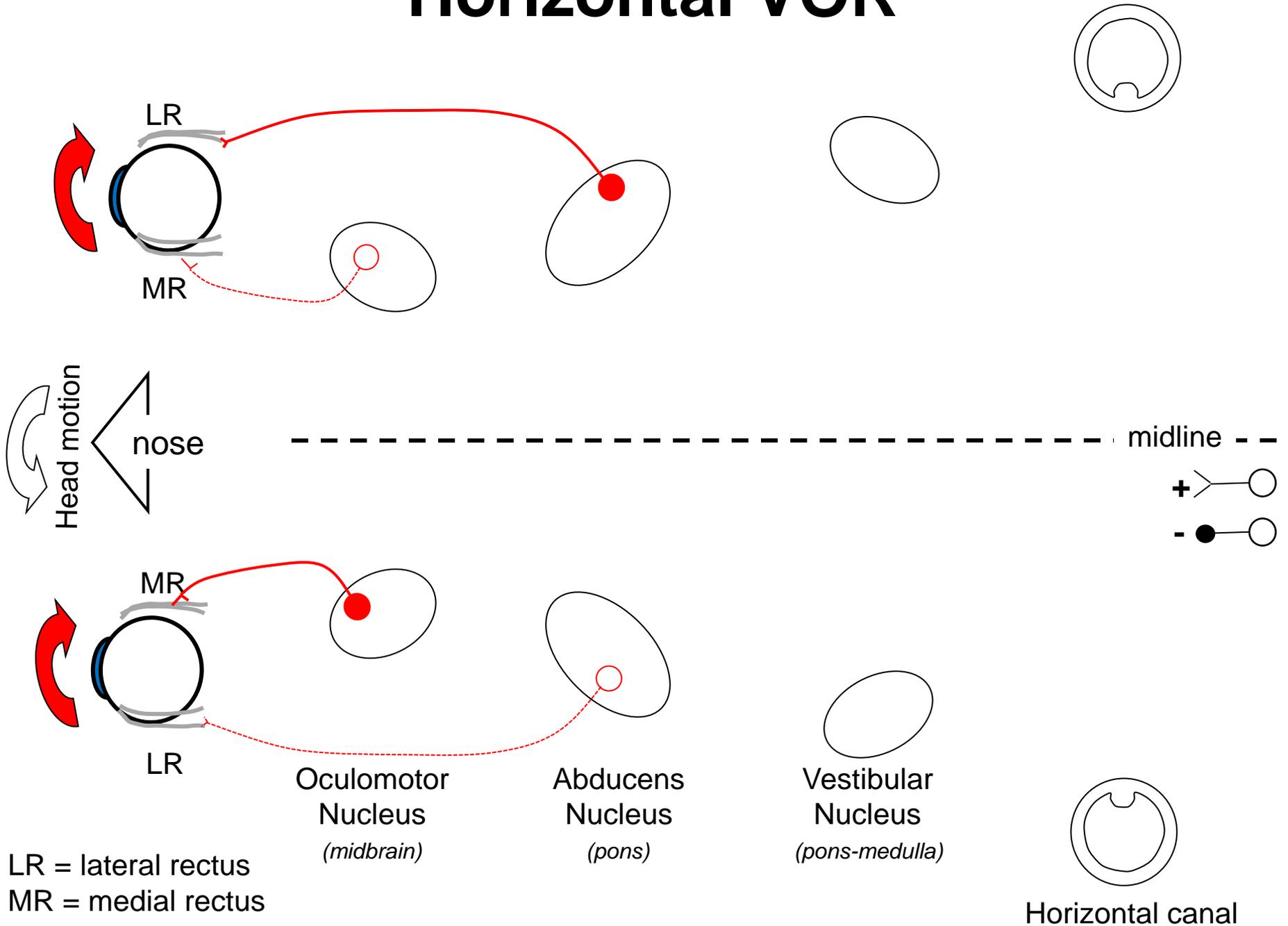
Muscles organized into
3 orthogonal pairs



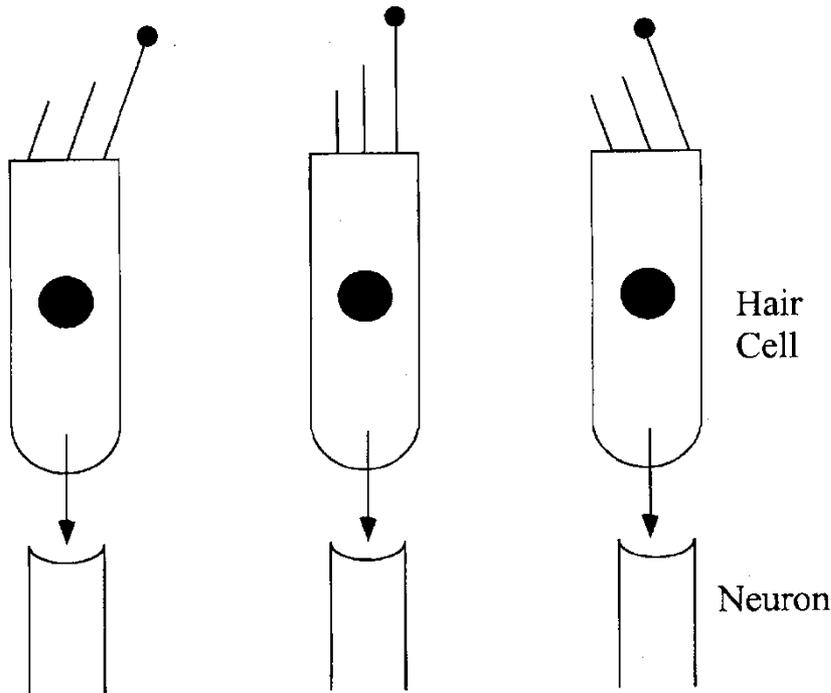
Canals organized into
3 orthogonal planes



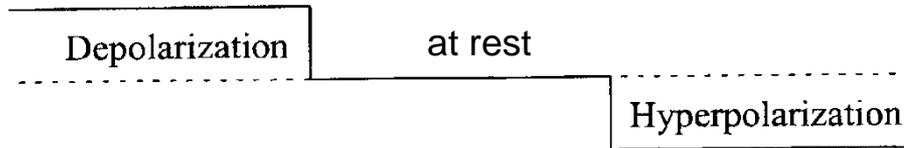
Horizontal VOR



Vestibular hair cell and afferent response



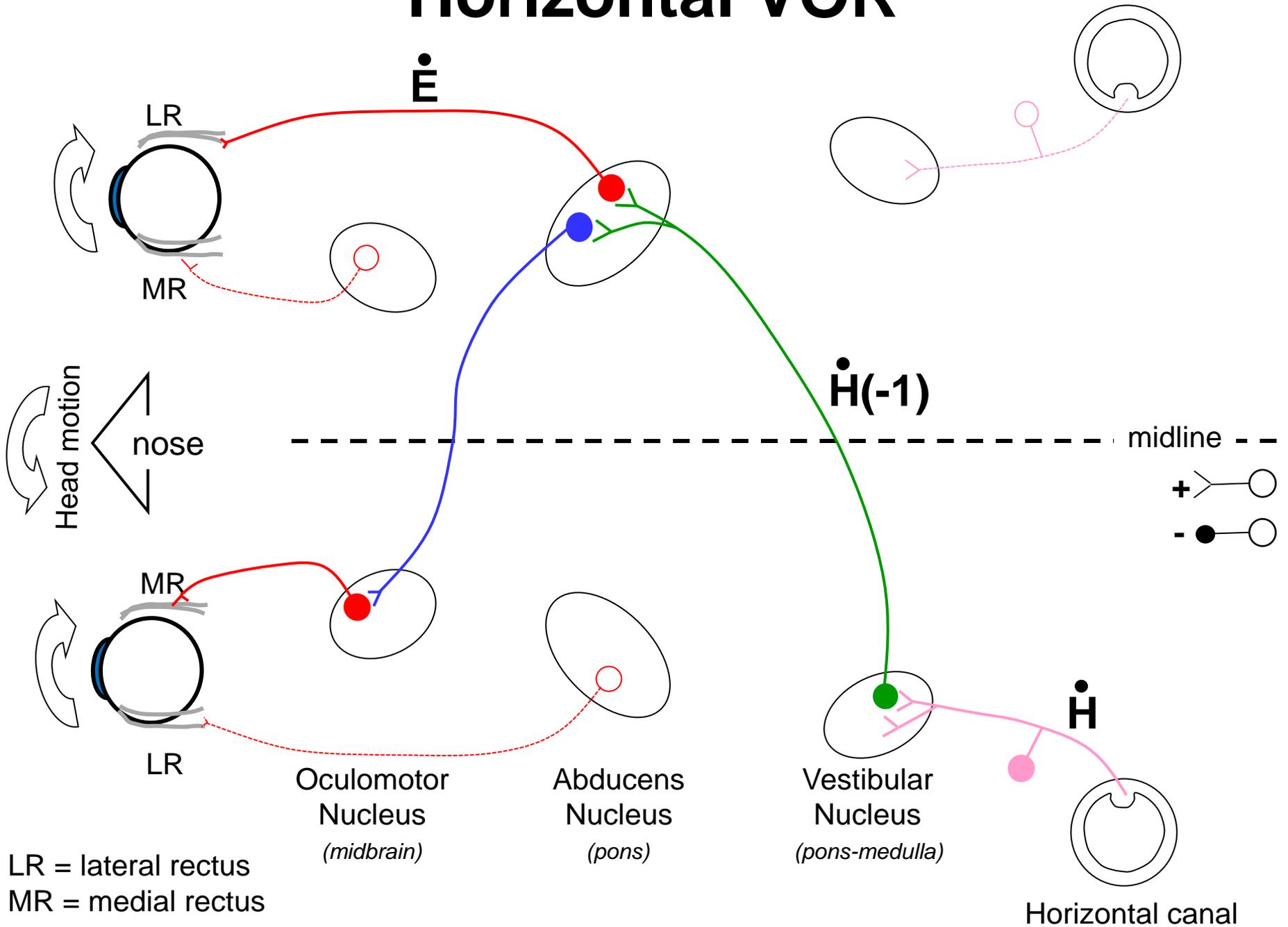
Opponent processing: afferent has resting discharge and can therefore signal both directions of head motion via increase or decrease in activity



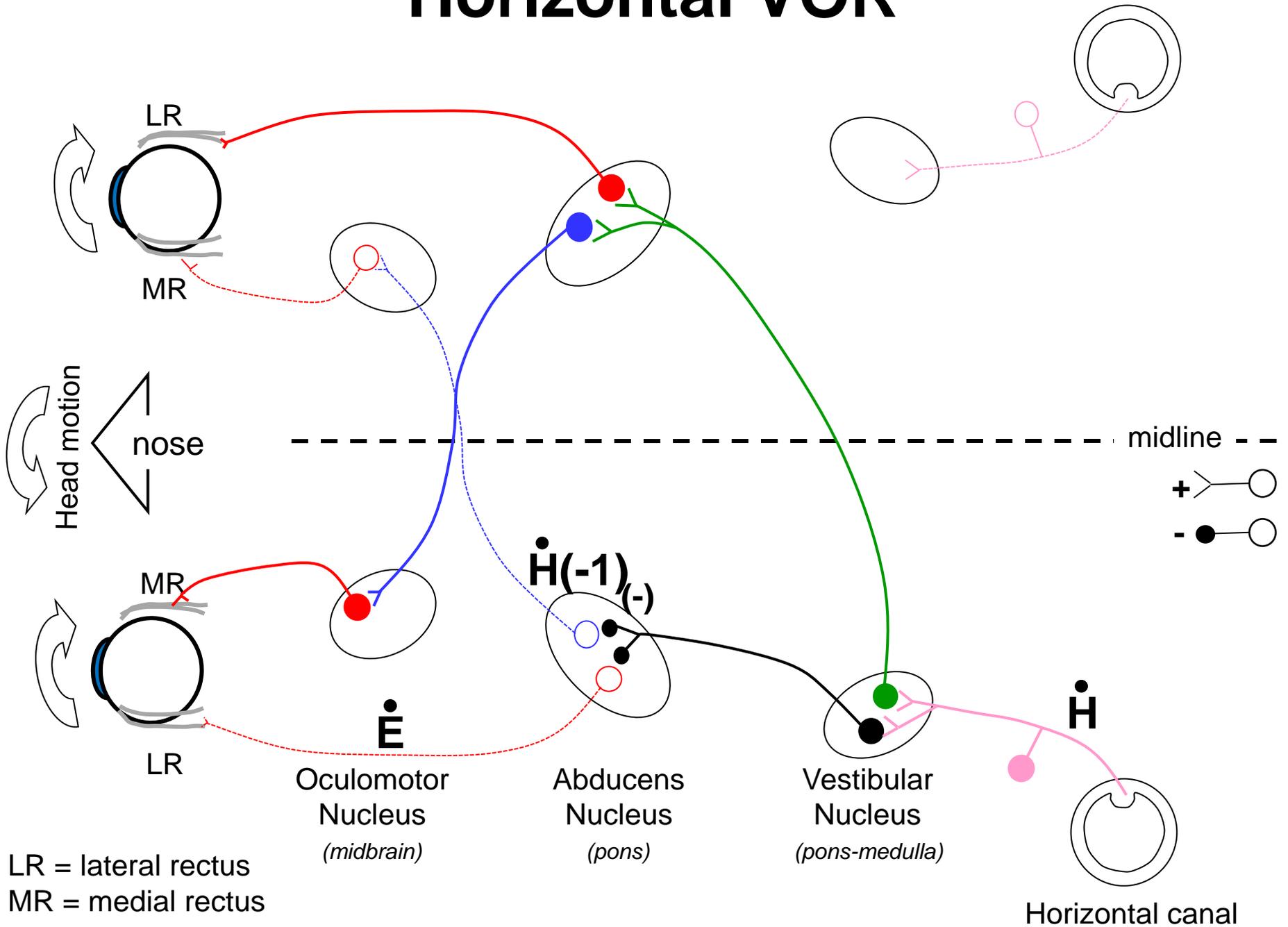
Hair cell (generator potential)

Primary vestibular afferent
(action potentials to cns via 8th nerve)

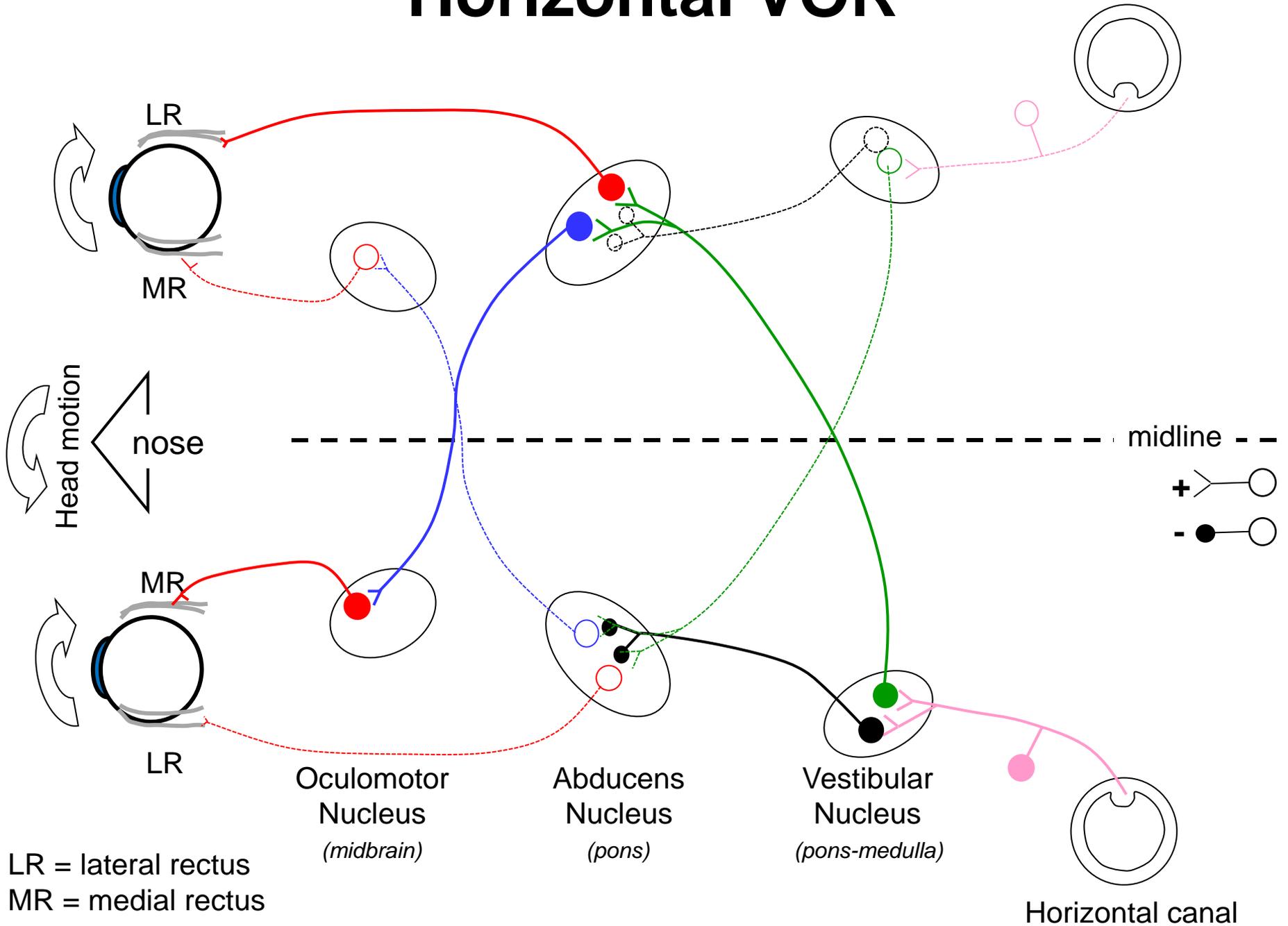
Horizontal VOR



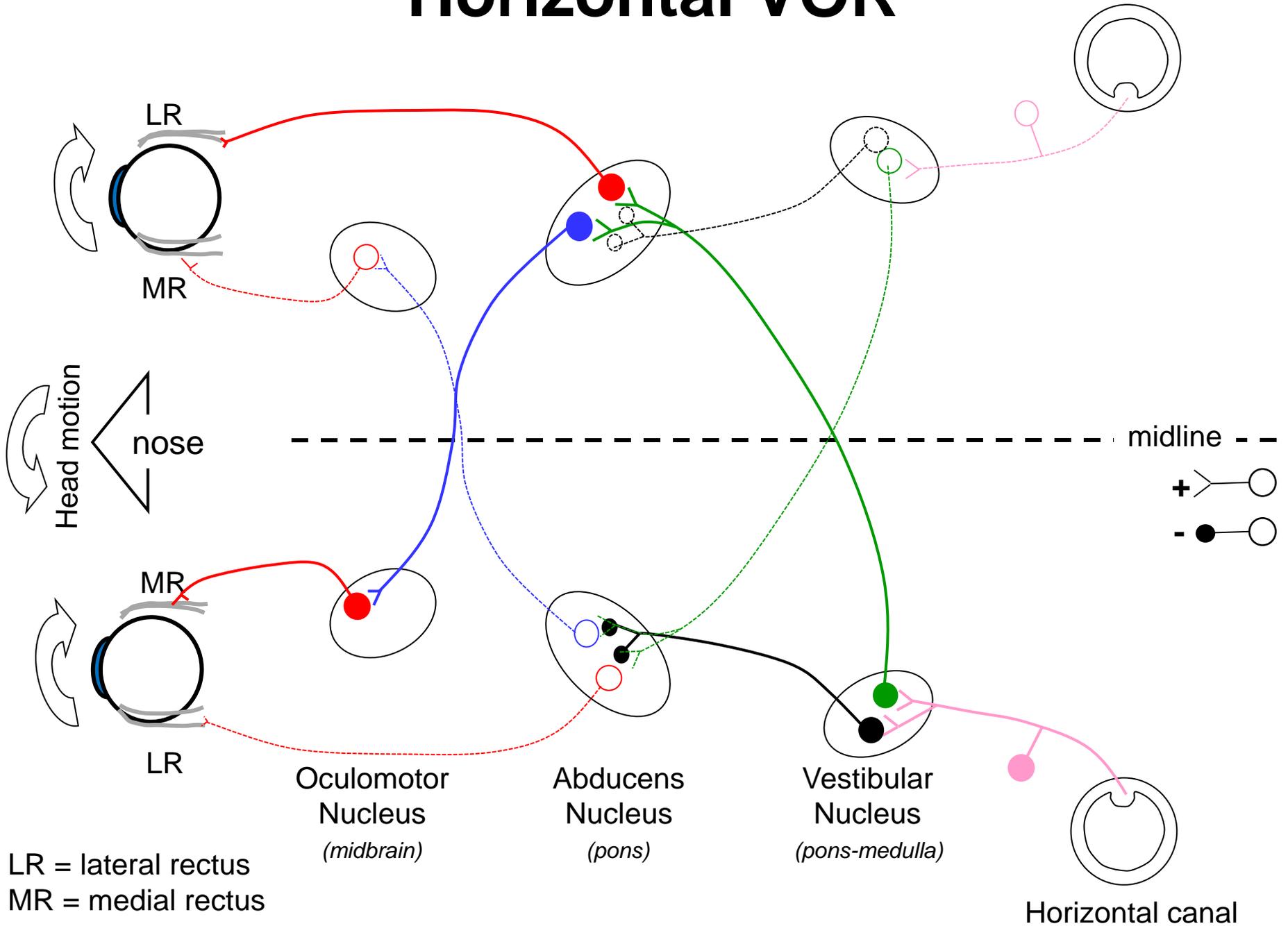
Horizontal VOR



Horizontal VOR



Horizontal VOR



LR = lateral rectus
MR = medial rectus

Oculomotor Nucleus
(midbrain)

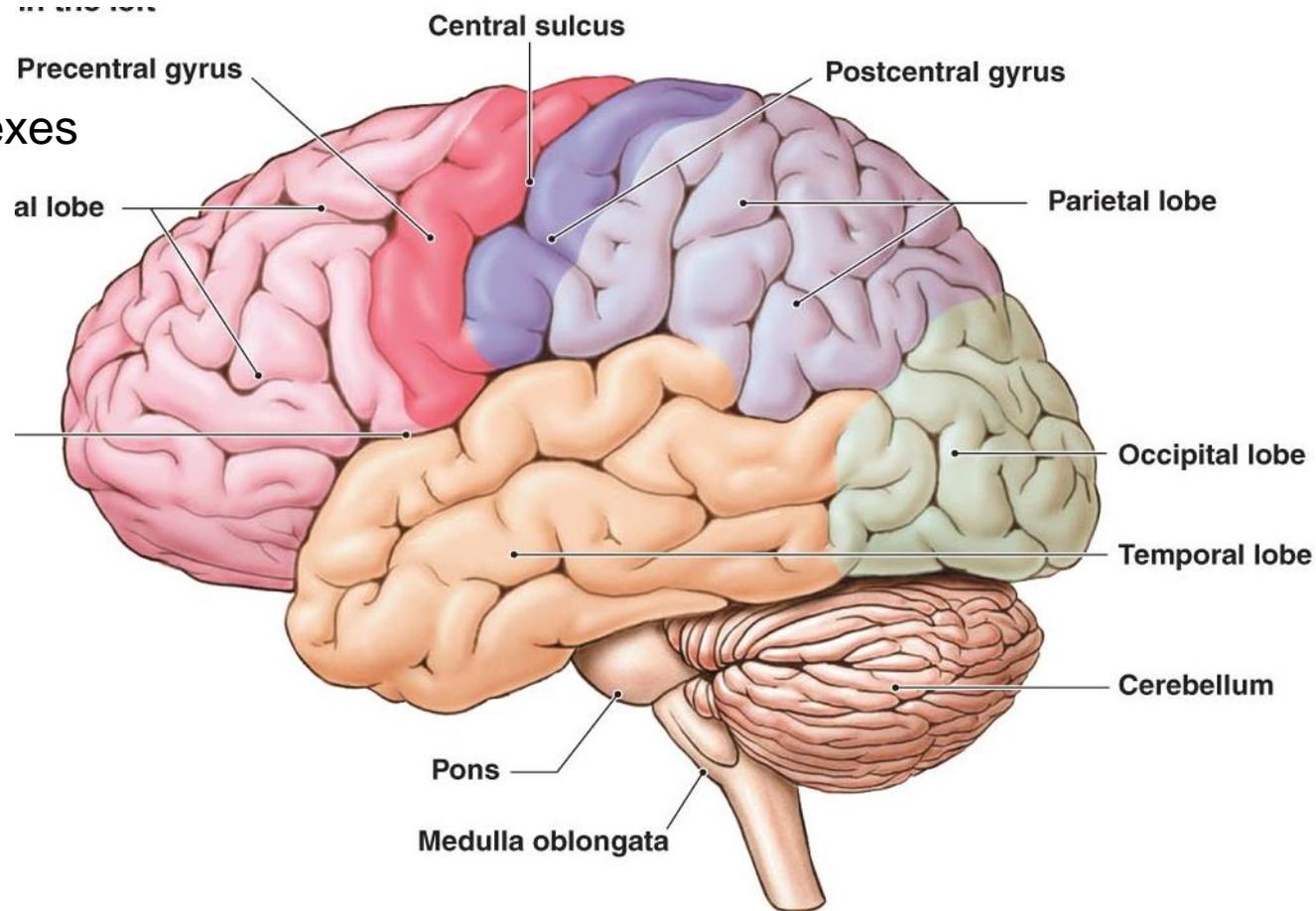
Abducens Nucleus
(pons)

Vestibular Nucleus
(pons-medulla)

Horizontal canal

Systems Neuroscience in neurosurgery

- Visual system
- Auditory system
- Somatosensory system
- Motor systems
- Limbic system
- Cranial nerves and reflexes
- Association cortex



Systems Neuroscience in neurosurgery

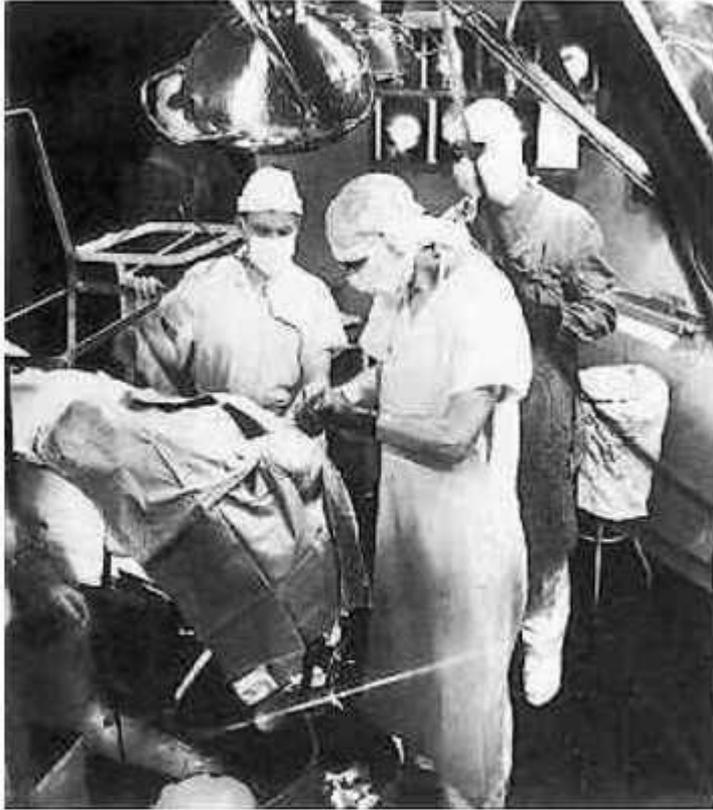
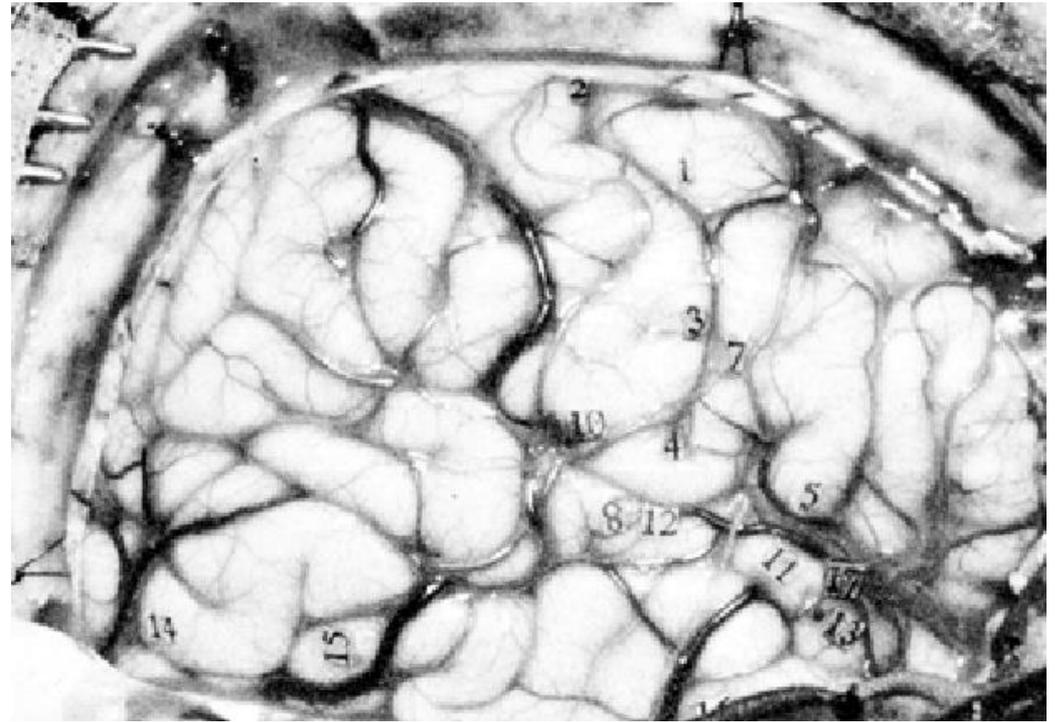
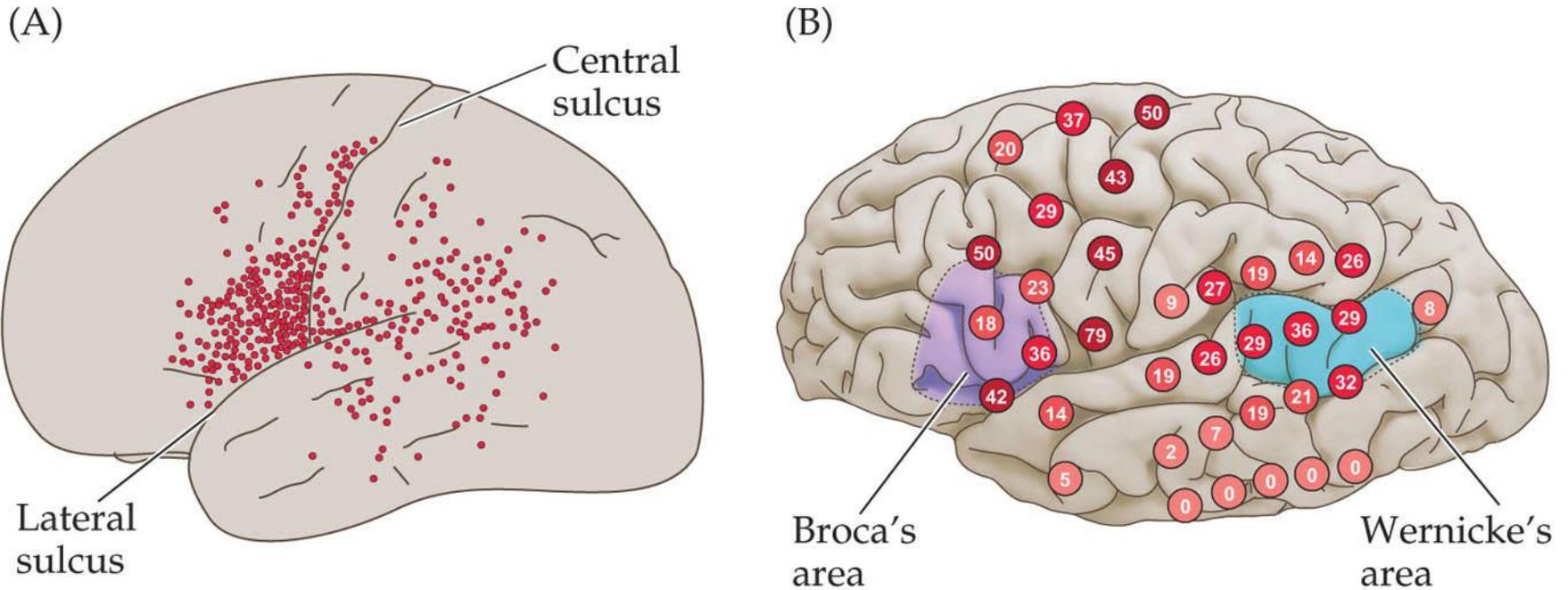


FIG. 6. Wilder Penfield, in full head mask, sutures surgical drapes to the scalp (Montreal Neurological Institute, circa 1946). The arrangement of the drapes is reminiscent of his sketches of Cushing's ritual.

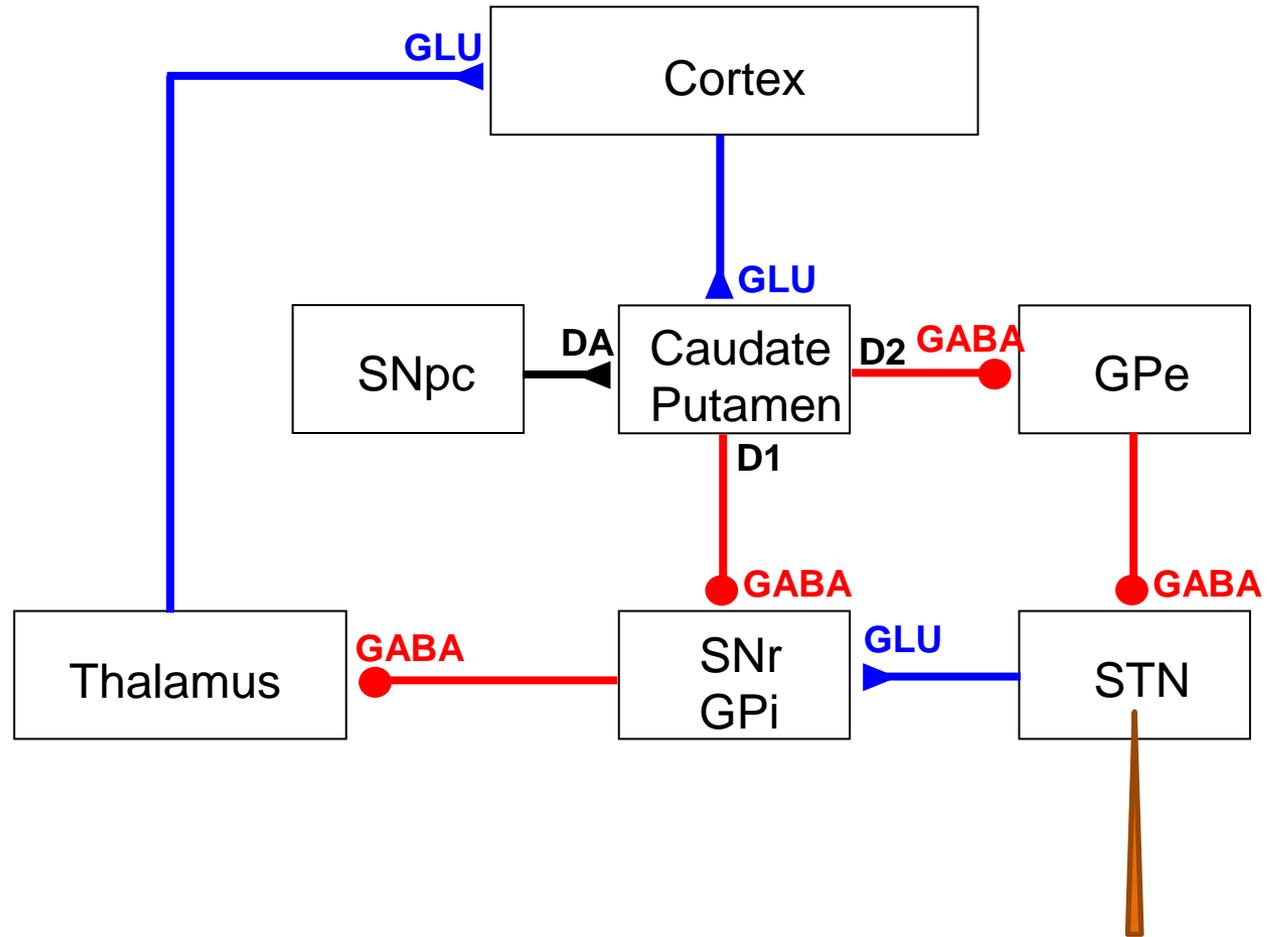
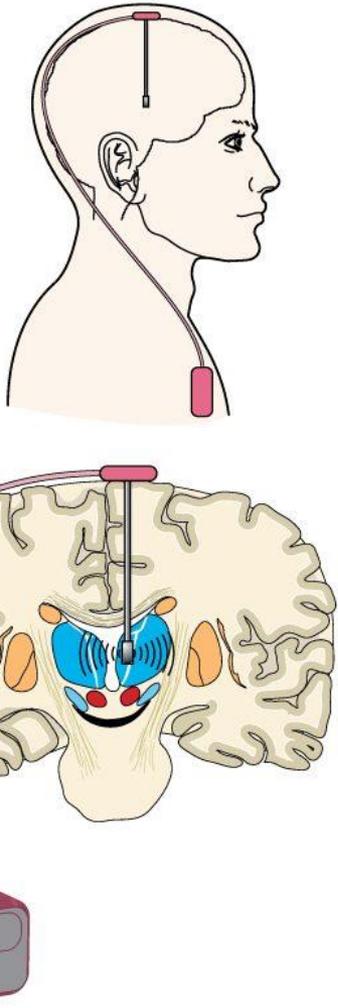


Dr. Wilder Penfield

Variability in Localization of Cortical Speech Areas



Systems Neuroscience in neurosurgery

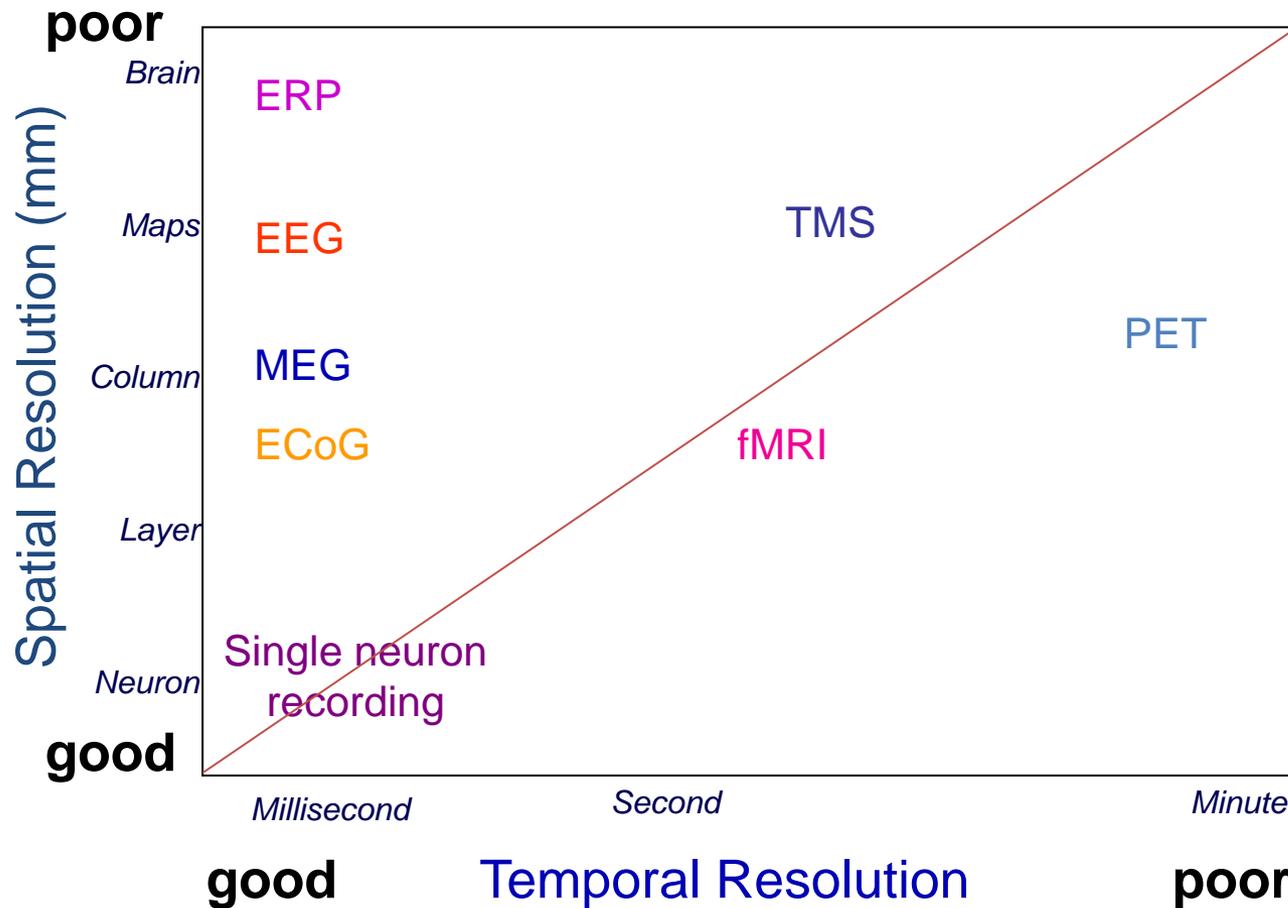


Stimulate subthalamic nucleus to treat Parkinson's disease

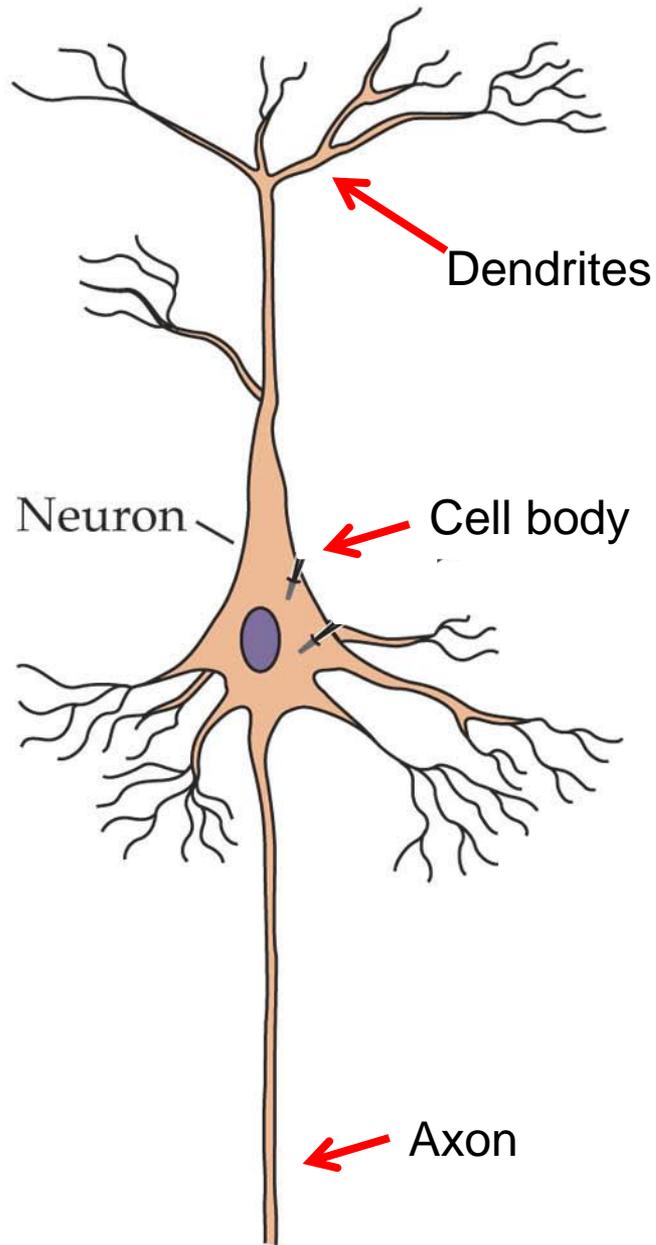
Techniques to measure neural activity

- Intracellular recording
- Extracellular recording
- Multi-electrode arrays
- Imaging: functional Magnetic Resonance Imaging (fMRI)
- Imaging: Positron Emission Tomography (PET)
- optogenetics

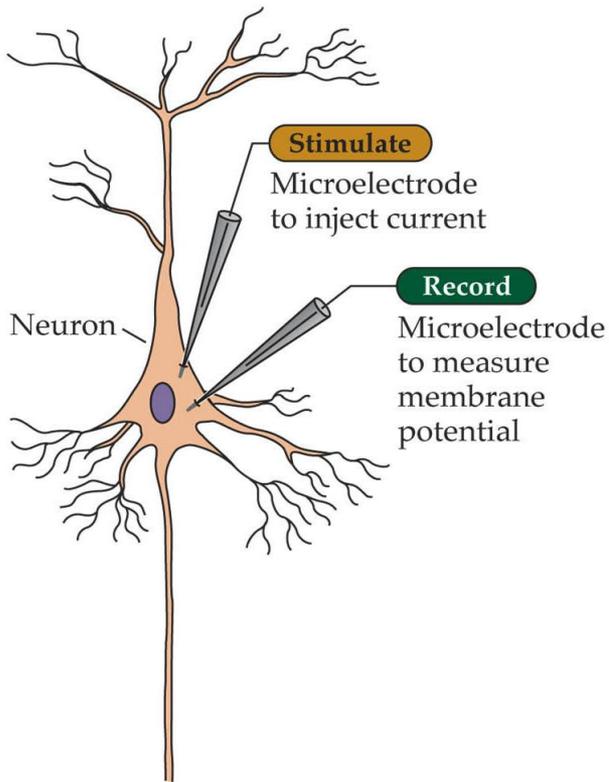
Spatial vs. Temporal Resolution Tradeoff



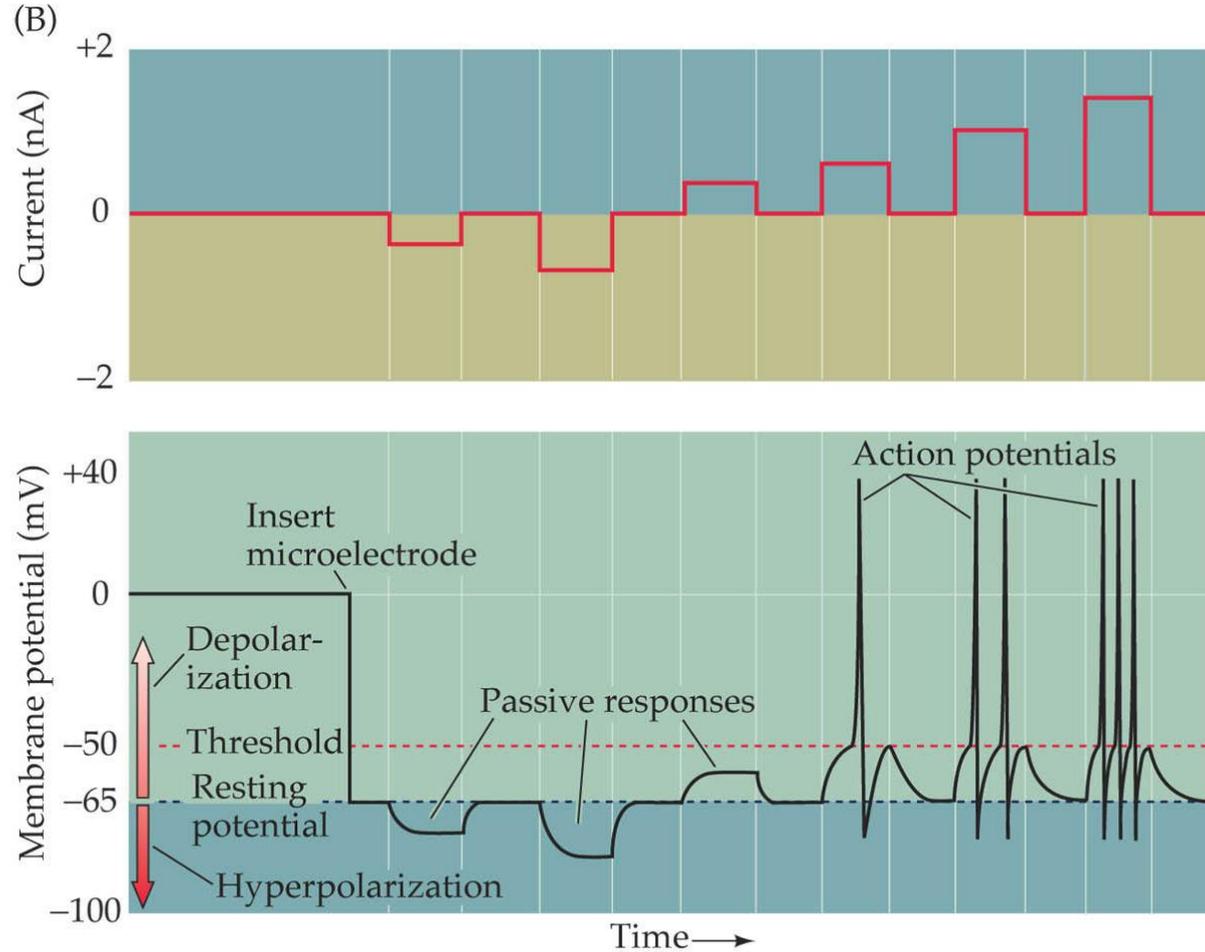
(A)



Intracellular recording reveals subthreshold events

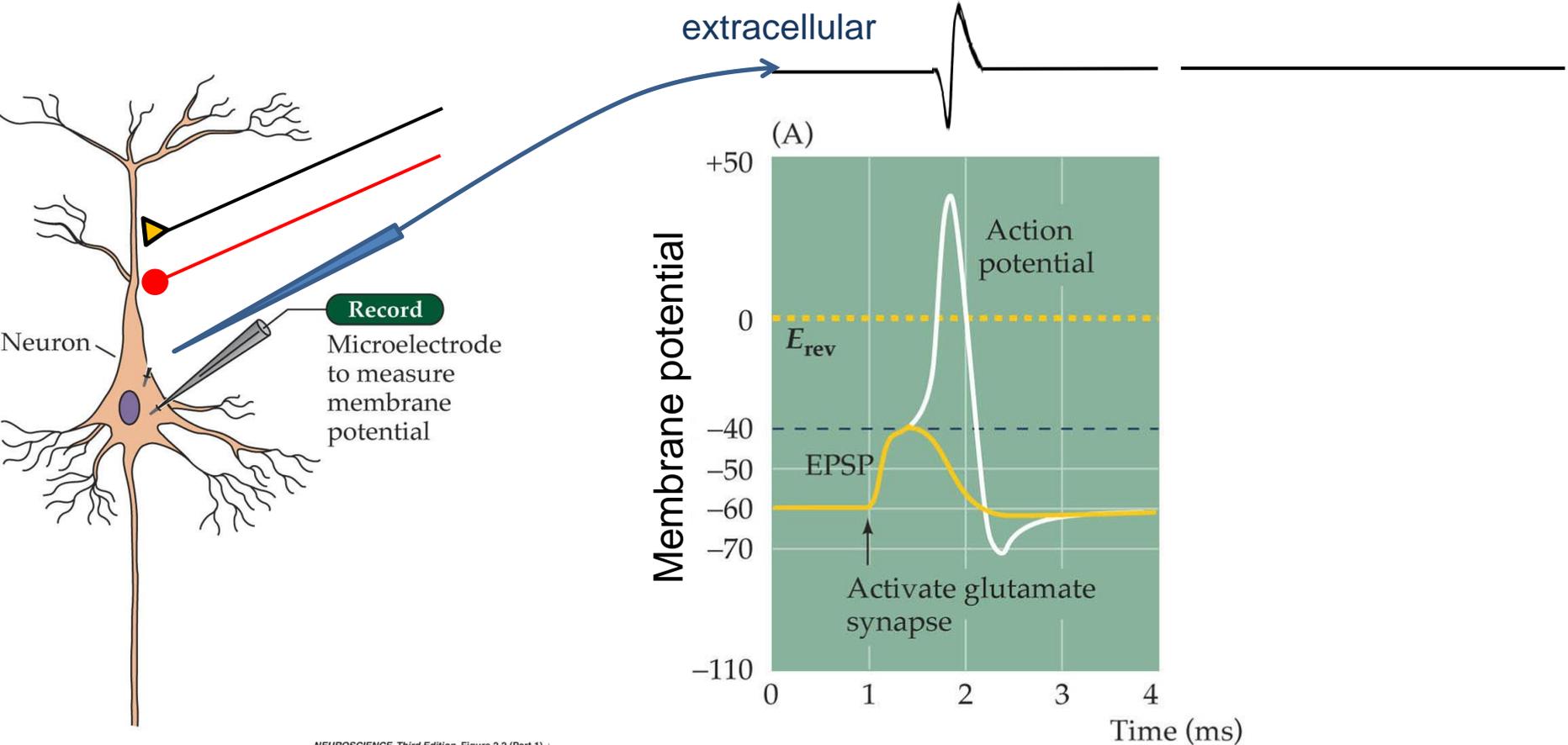


NEUROSCIENCE, Third Edition, Figure 2.2 (F)



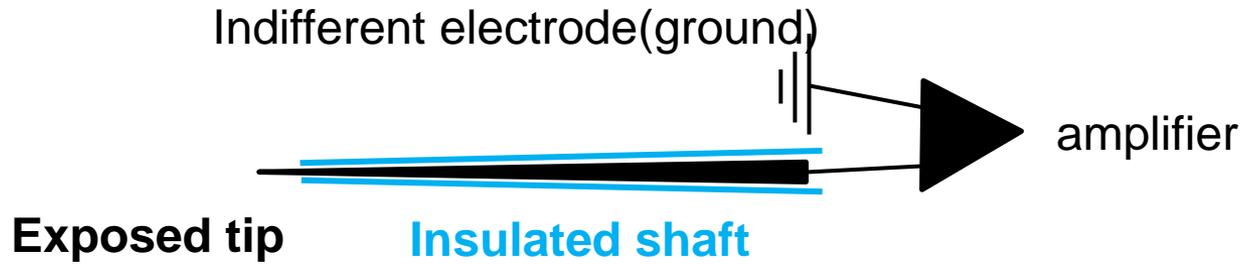
NEUROSCIENCE, Third Edition, Figure 2.2 (Part 2) © 2004 Sinauer Assn

Extracellular recording misses subthreshold events

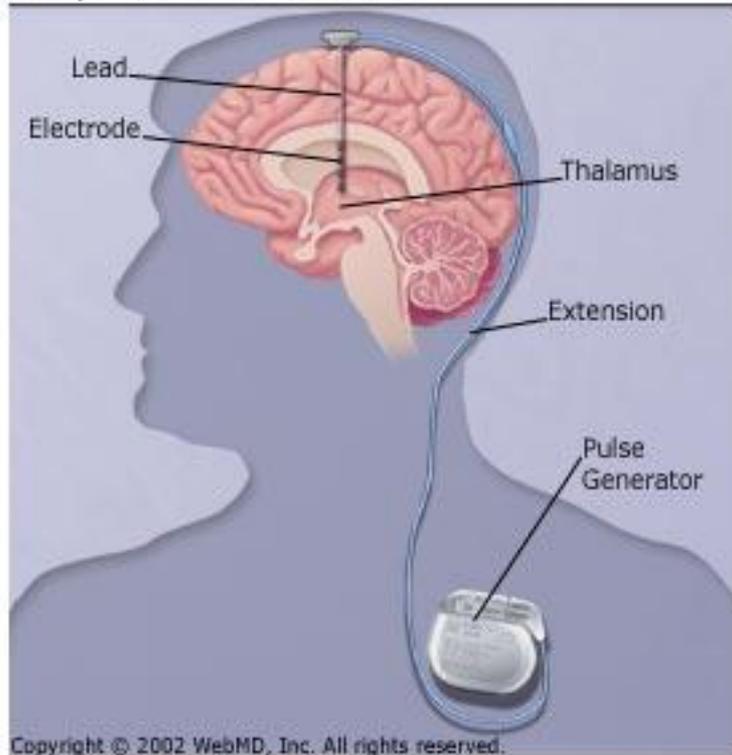


NEUROSCIENCE, Third Edition, Figure 2.2 (Part 1)

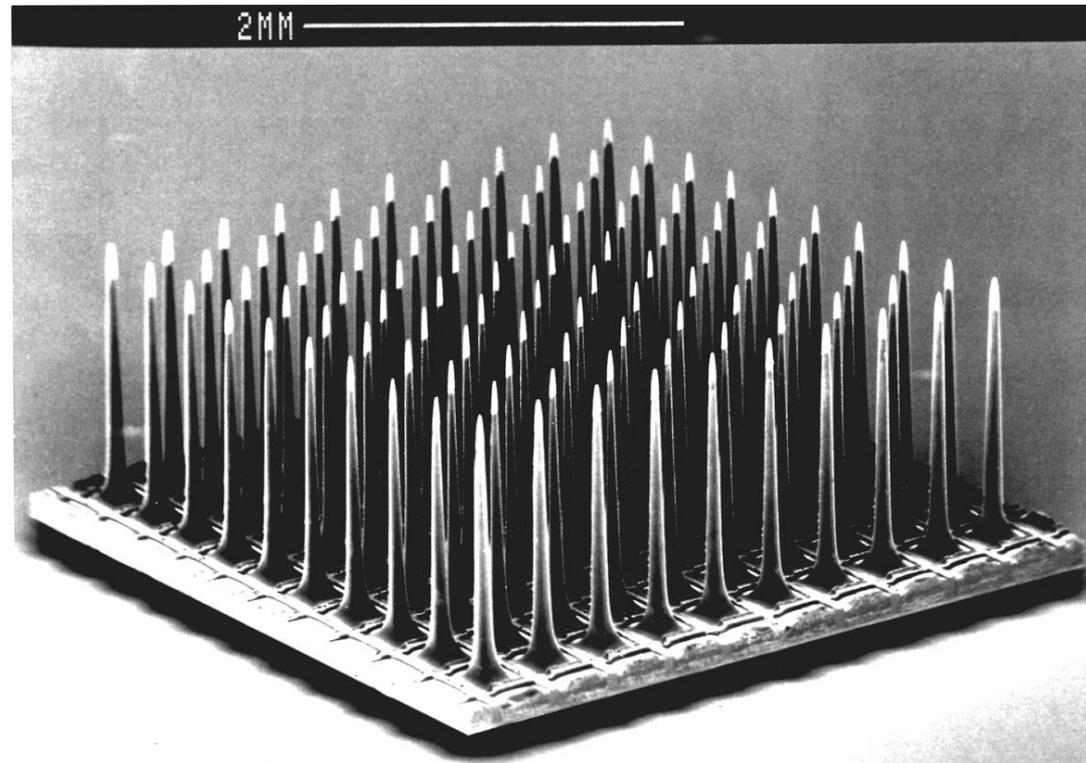
Microelectrodes are used to record extracellularly



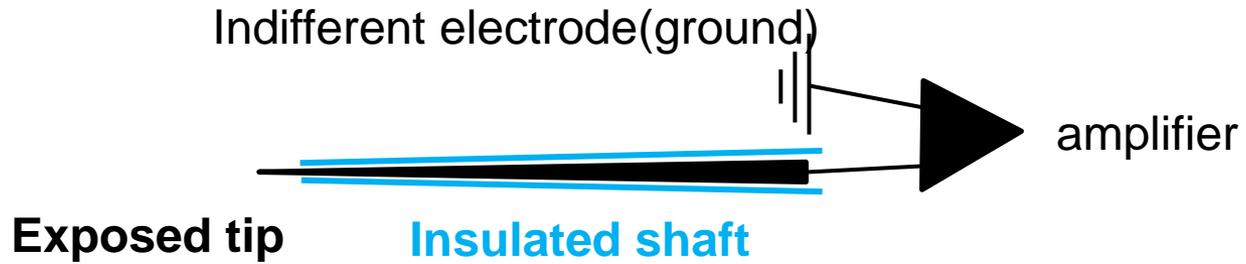
Deep Brain Stimulation



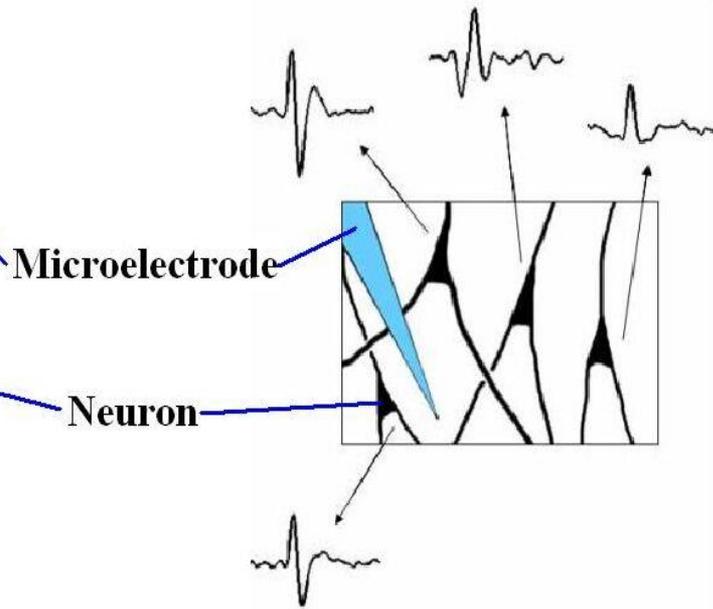
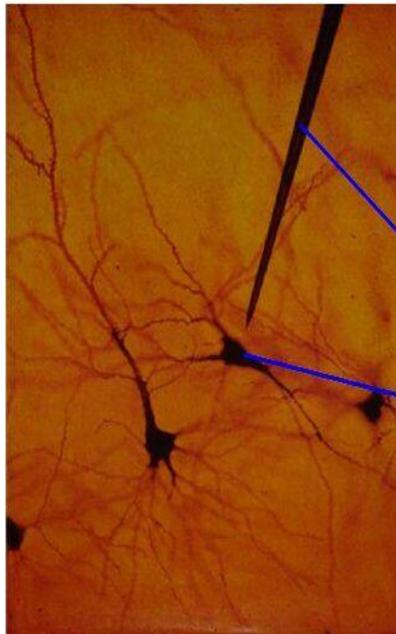
Utah array (10 x 10 array of electrode)



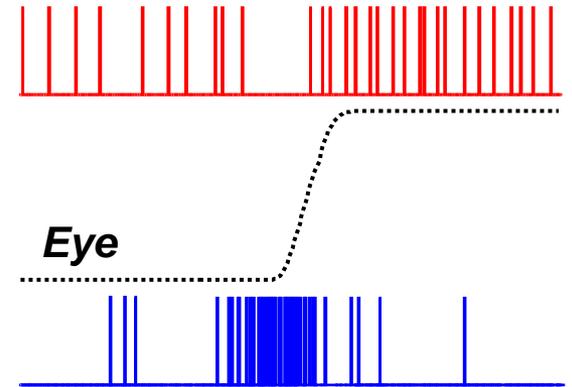
Microelectrodes are used to record extracellularly



Microelectrode in neuropil

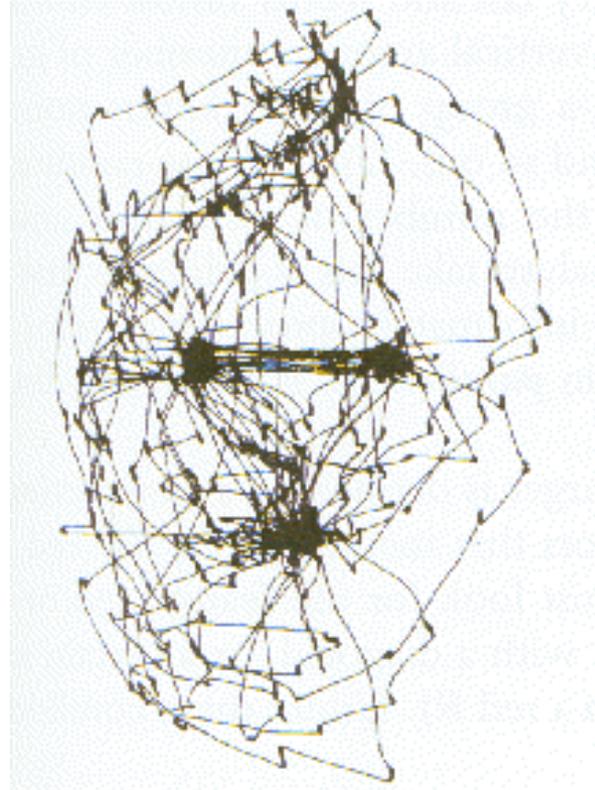


Correlate to behaviour

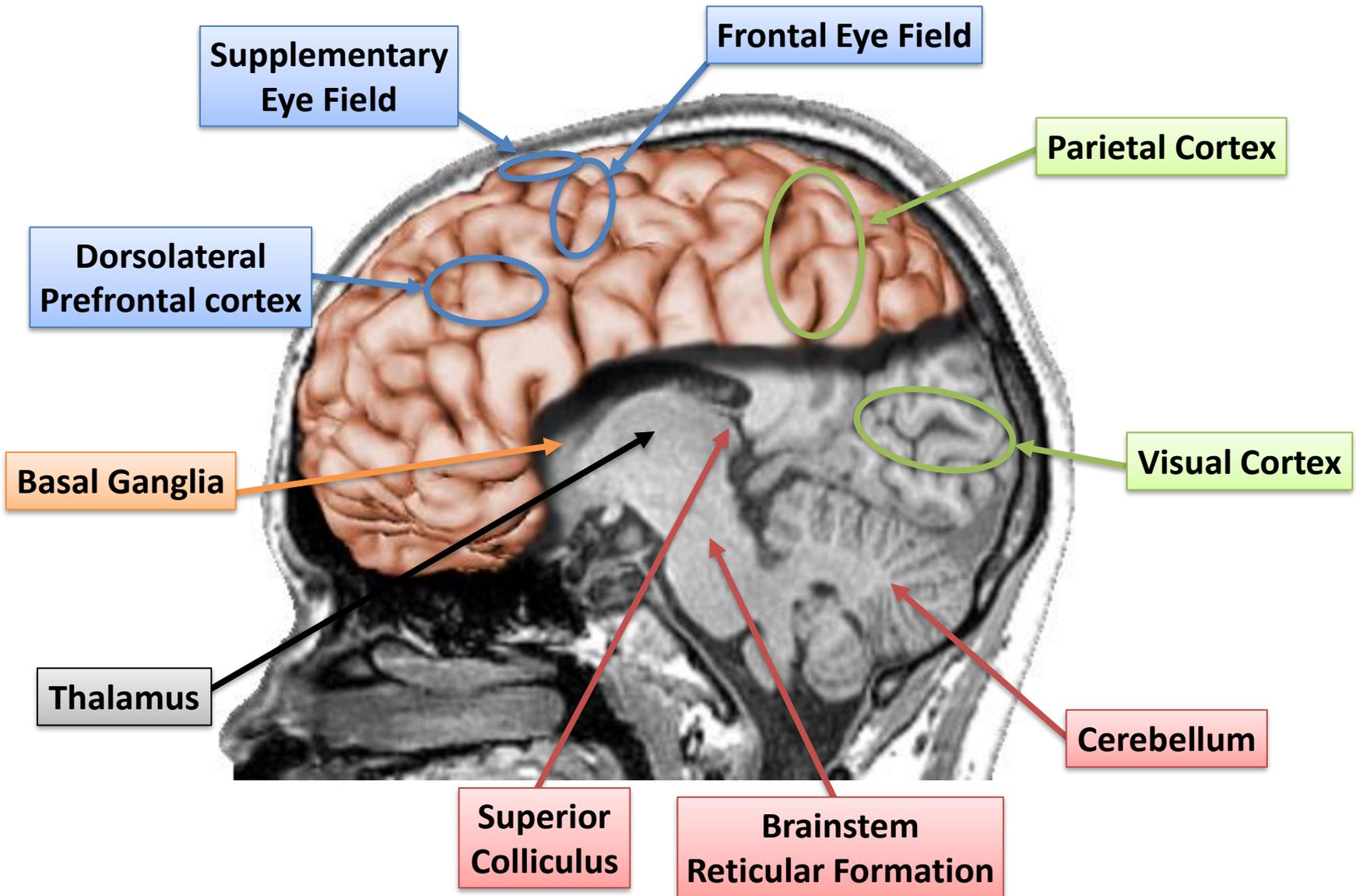


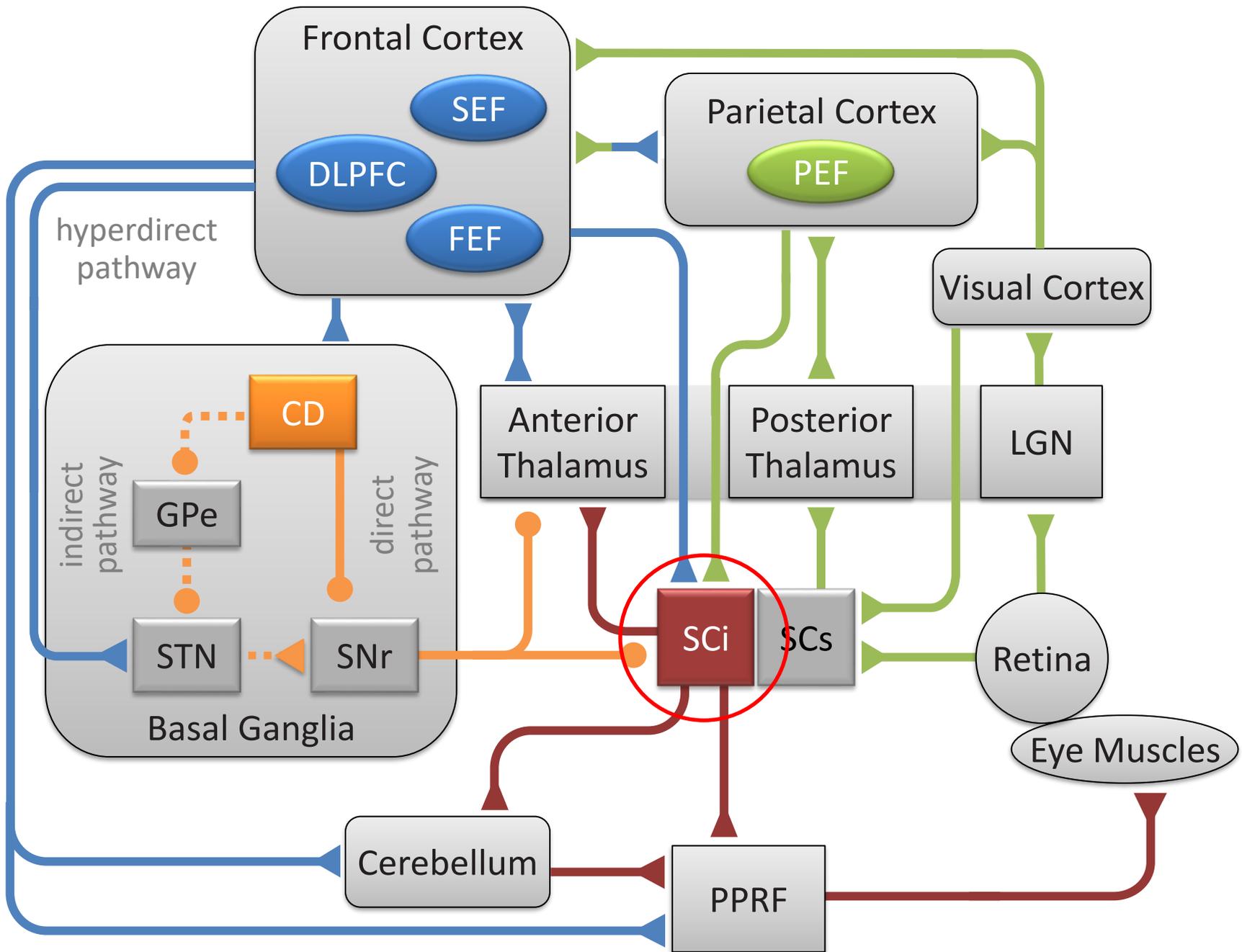
Saccade-Fixation Behaviour

Saccades allow us to scan the visual field and intermittently focus our *attention* on the parts of the scene that convey the most *significant information*.

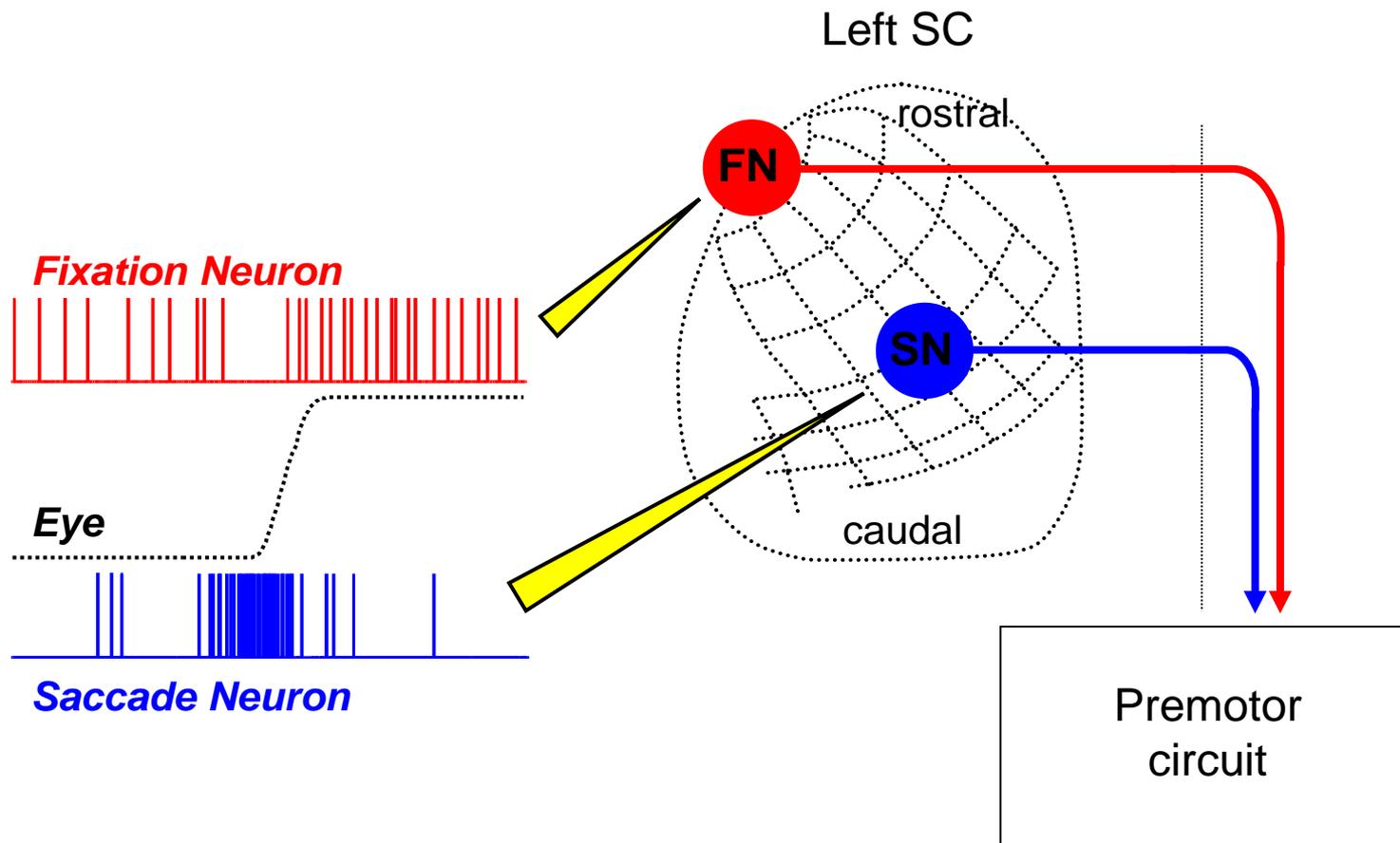


Multiple Brain Areas Involved in Controlling Saccadic Eye Movements



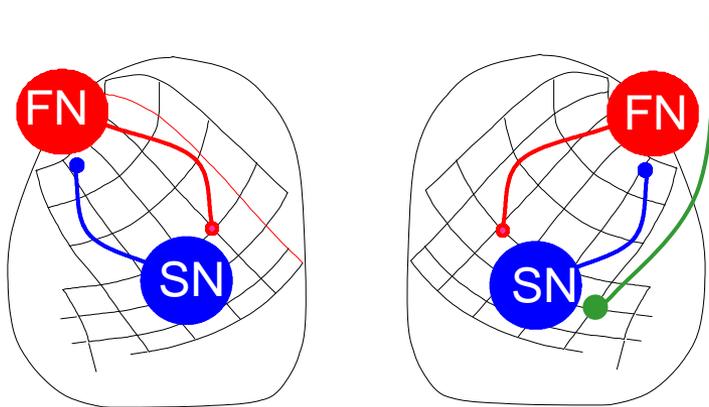


A Saccade Map in the Superior Colliculus: Contains **Fixation** and **Saccade** Neurons



How to Establish Causation?

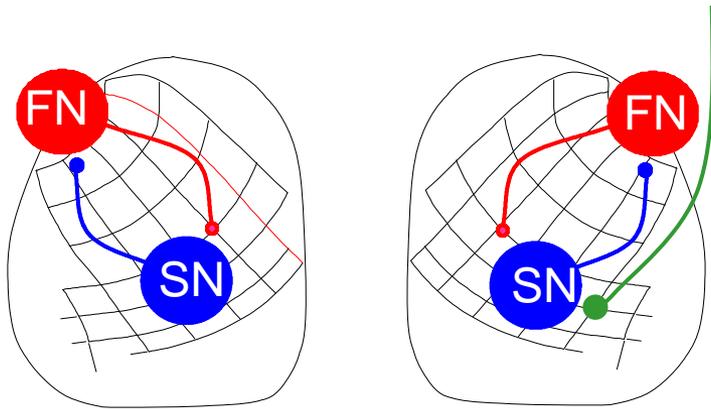
Hypothesis



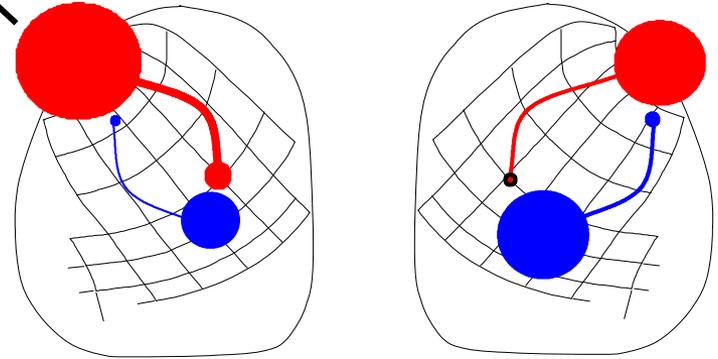
Microstimulation has problems because we cannot differentiate between activation of local SC processes or activation of fibers of passage

Pharmacological Manipulation of Fixation Signal

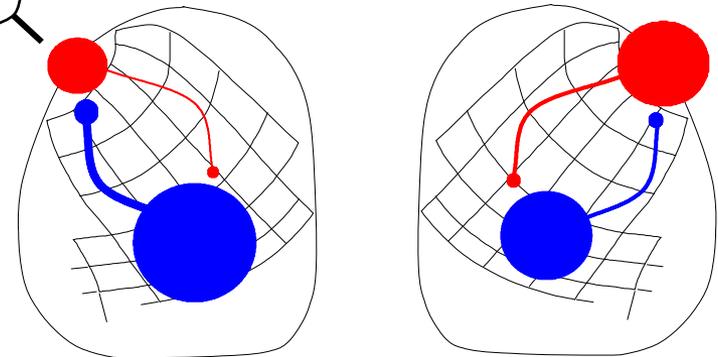
Hypothesis



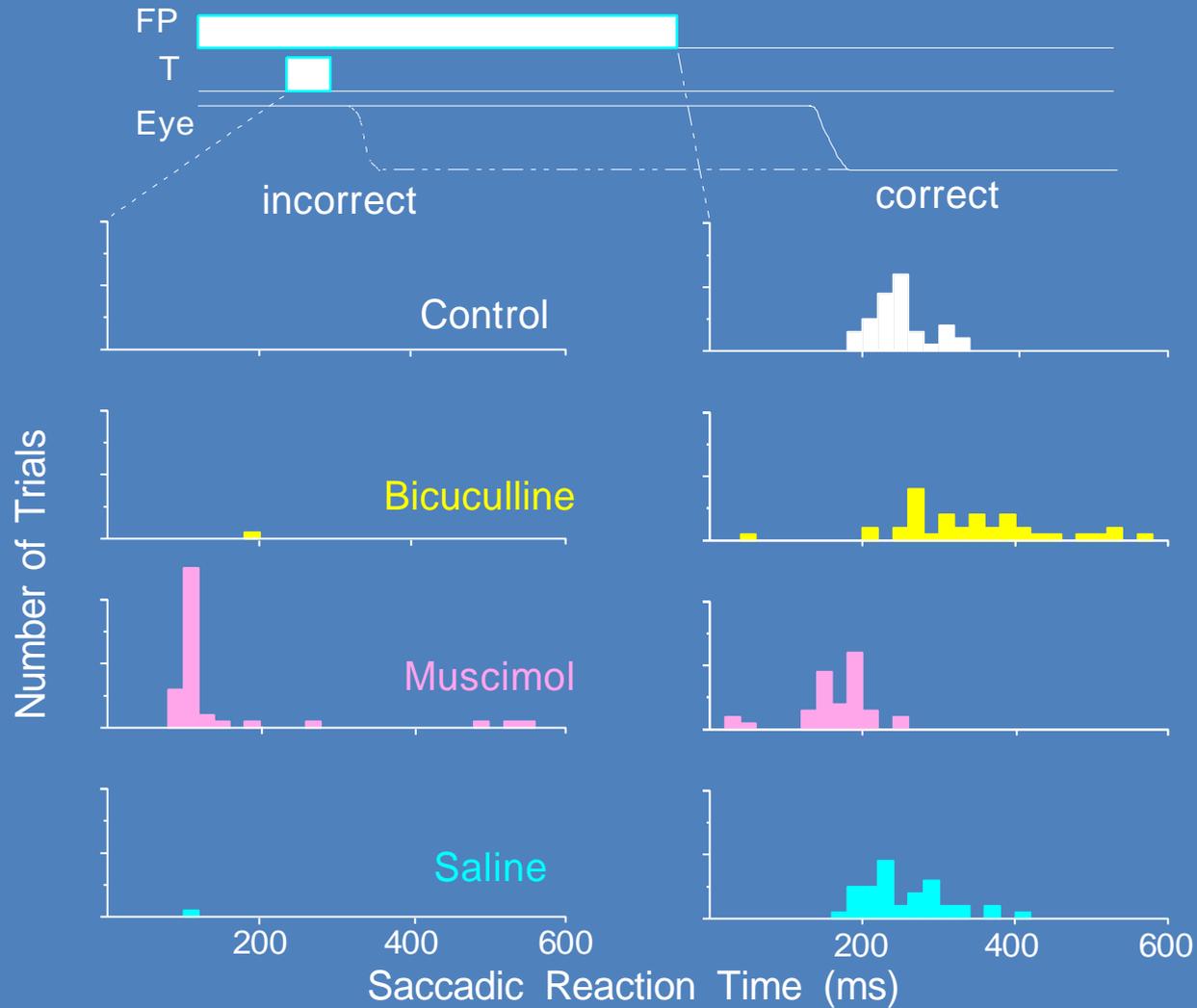
Bicuculline GABA_A antagonist



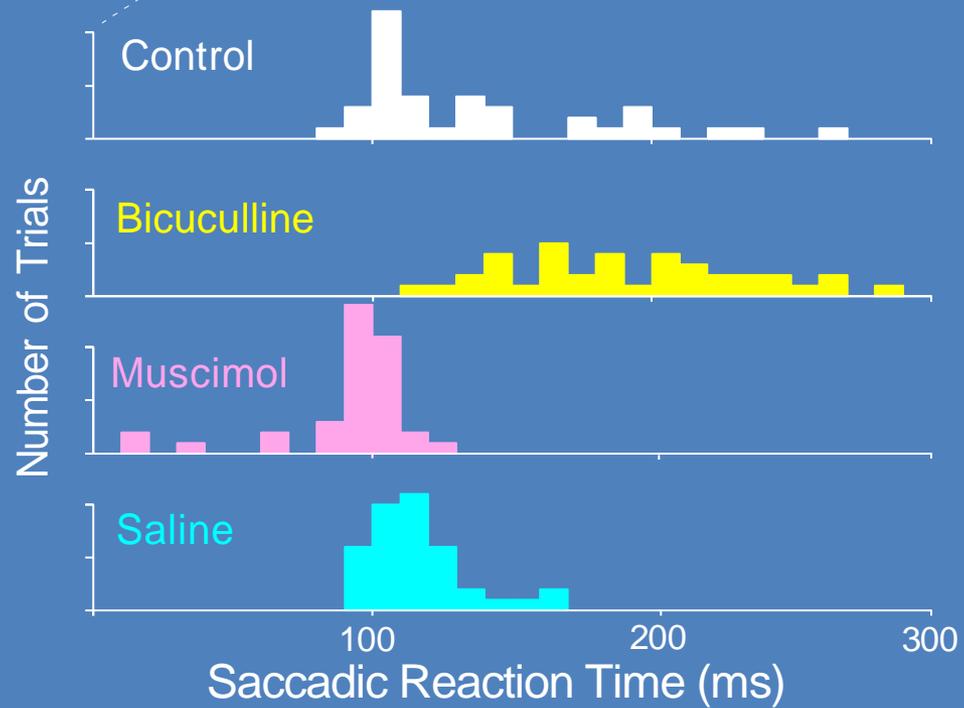
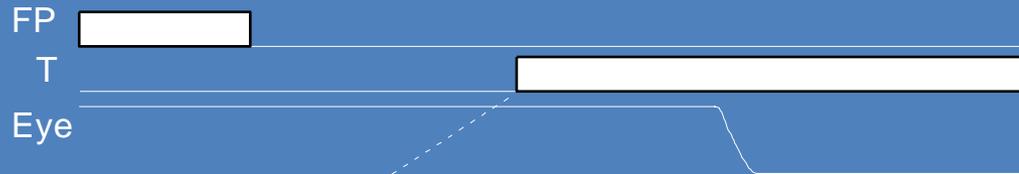
Muscimol GABA_A agonist



Memory-Guided Saccade Task



Gap Saccade Task



Systems Neuroscience